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US Space Superiority: It Was Good While It Lasted

Exploring the Contesting and Congesting Of the Space Domain

by

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Disclaimer

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Abstract

The United States' current state of space superiority may soon be a thing of the past because other nations are developing new capabilities that are both contesting and congesting the space domain. Therefore, the United States must seriously consider future courses of action to mitigate the effects of a congested and contested space domain. This research paper uses the scenario planning methodology to examine how the US dependence on the space domain may change in a more contested or congested space environment. Three fictional, yet plausible scenarios are developed to illustrate how US space superiority may be challenged approaching the year 2025 in conjunction with driving forces such as the International Traffic in Arms Regulation, global demands for energy, and emerging cyberspace capabilities. Through these scenarios, a rather gloomy picture emerges of what might happen if the United States loses its robust space capabilities. Consequently, five recommendations are made for decision makers to consider in the hope that the trends and driving forces contributing to the aforementioned scenarios can be reversed before any real damage is done.

Introduction

What will be the future of United States' space capabilities in a more contested and congested space environment? The United States' current state of space superiority may soon be a thing of the past because other nations are developing new capabilities that are both contesting and congesting the space domain. The amount of space debris in orbit has been increasing at an alarming rate, and some countries have even deliberately created debris as part of anti-satellite tests.[1] Some estimates predict that there are over 300,000 artificial objects in earth orbit greater than 1 centimeter in size, and if left unchecked, could have disastrous effects on active satellites.[2] Additionally, the vulnerability of space assets to interference and disruption provides the grounds to view space as a contested domain in which defense of assets and capabilities becomes a priority.[3] To solve these problems, many nations' policymakers are advocating measures that minimize or prevent space debris and advocate the cooperative interpretation of the Outer Space Treaty of 1967.[4] Without an active debris removal system and strict adherence to a gentlemen's agreement, prevention and cooperation alone may not be enough to ensure the United States maintains its superiority in the space domain. Therefore, with the increasing threat of space debris, coupled with adversary nations developing their own capabilities, the United States must seriously consider future courses of action to mitigate the effects of a congested and contested space domain.

This research paper uses the scenario planning methodology to examine how the US dependence on the space domain may change in a more contested or congested space environment. Three scenarios are developed to illustrate how US space superiority may be challenged approaching or by the year 2025. The scenarios are fictional, yet plausible forecasts of the future in order to identify driving forces that will shape the space domain and ultimately

impact US space-based capabilities. The paper discusses the trends leading up to this point, plausible scenarios, and courses of action for national leadership to pursue if any one scenario plays out.

Background and Analysis

For as long as humans have been placing man-made objects into orbits above the Earth, man has also been littering this vast area with debris from the technology it takes to get to space. The early years did not seem to exhibit any danger in having a few extra objects circling the Earth along with the high-value satellites because the vastness of space provided an extremely low probability that two objects would impact each other. However, over the last 54 years, space faring nations have created an environment in Earth orbit where the once object-void domain is actually becoming congested. Figure 1, produced by the National Aeronautics and Space Administration (NASA) illustrates how many objects are being tracked around the globe.

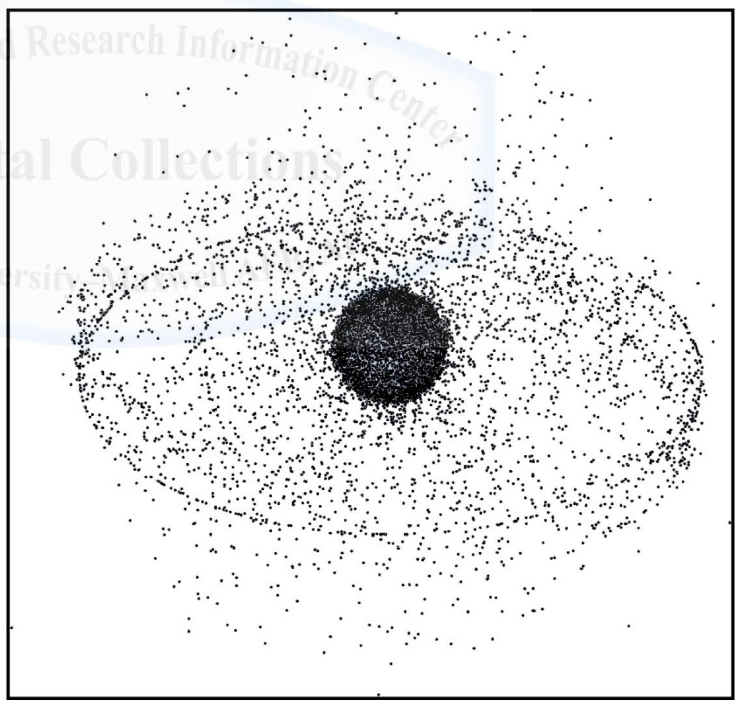


Figure 1: Objects in earth orbit (not to scale)

Over the years, 11 countries have independently demonstrated the capability to launch objects into earth orbit.[5,6] However, due to the extreme difficulties and costs associated with launching satellites into orbit, the number of entities that can achieve orbit today is only eight if

one considers the European Space Agency (ESA) to be a single entity.[7,8] Consequently, many nations have partnered with these space faring nations in a launch-for-hire capacity to achieve their space capabilities. All together, there are around 60 countries or government consortia that own or operate active satellites in space.[9] One might ponder, "If there are so few entities capable of launching satellites into orbit, then why is it so congested?" The fact is that most satellites remain in orbit long after their service life because there were not provisions to de-orbit them or move them out of the way until a few years ago. When satellites stopped functioning, countries would just replace the satellite with a new one and move the old satellite to a location nearby. A similar analogy would be if an individual never sold or traded their vehicles when they bought a new car, but instead just parked their old vehicles out of the way, but still in their front or back yard. After only a few years the individual's yard would be littered with non-functioning vehicles and would literally look like a small junkyard.

Only a subset of the eight nations capable of launching satellites into orbit actually has the capability to track other satellites in space. The United States has a world-wide Space Surveillance Network, comprised of radar and optical sensors, capable of tracking and cataloging all objects larger than 10 centimeters.[10] The Joint Space Operations Center at Vandenberg Air Force Base maintains this catalog and shares most of it with the rest of the world. The Russian Federation also maintains a similar capability; however, it does not share its information with the general public.[11] Some states in Europe, such as Germany, France, and the United Kingdom, have limited space tracking capability and are working to expand that capability through an ongoing Space Situational Awareness (SSA) program to serve both civil and military users.[12] Additionally, a group of commercial satellite operators have formed an international non-profit organization to increase the sharing of SSA data between satellite operators. This group began

providing conjunction assessments—a notification when two orbital objects approach a relatively close proximity with each other—and collision warning services to participating satellite operators in 2010.[13]

Space capabilities have proven to be almost priceless. Instantaneous world-wide communications to precision timing signals have literally changed the way our global economy operates. The current *US National Space Policy* draws attention to this idea by stating: “Now, we find ourselves in a world where the benefits of space permeate almost every facet of our lives.”[14] And then the policy goes on to state: “Decades of space activity have littered Earth’s orbit with debris; and as the world’s space-faring nations continue to increase activities in space, the chance for a collision increases correspondingly.”[15] This last statement is not merely a false alarm or an attempt to create unnecessary drama, but is actually highlighting a real and growing dilemma that could prove detrimental to all space-faring nations if left unresolved.

Congesting of the Space Environment

To date, there are several examples of satellites and spacecraft that have endured impacts from uncontrolled space debris. One famous example is a 0.2 millimeter fleck of paint that impacted the windshield of the space shuttle orbiter causing a 4-millimeter-diameter crater. The paint fleck was estimated to have a relative velocity of 3-6 km/sec (6,710 to 13,400 mph) on impact (Figure 2).[16] This is only one example of many documented collisions that have occurred in orbit. The reality is that every single piece of debris is, in

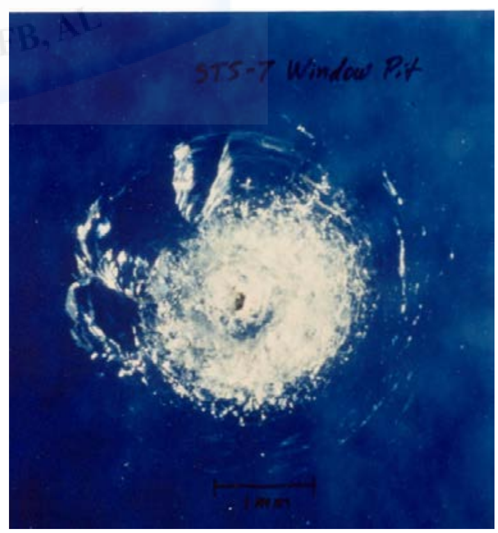
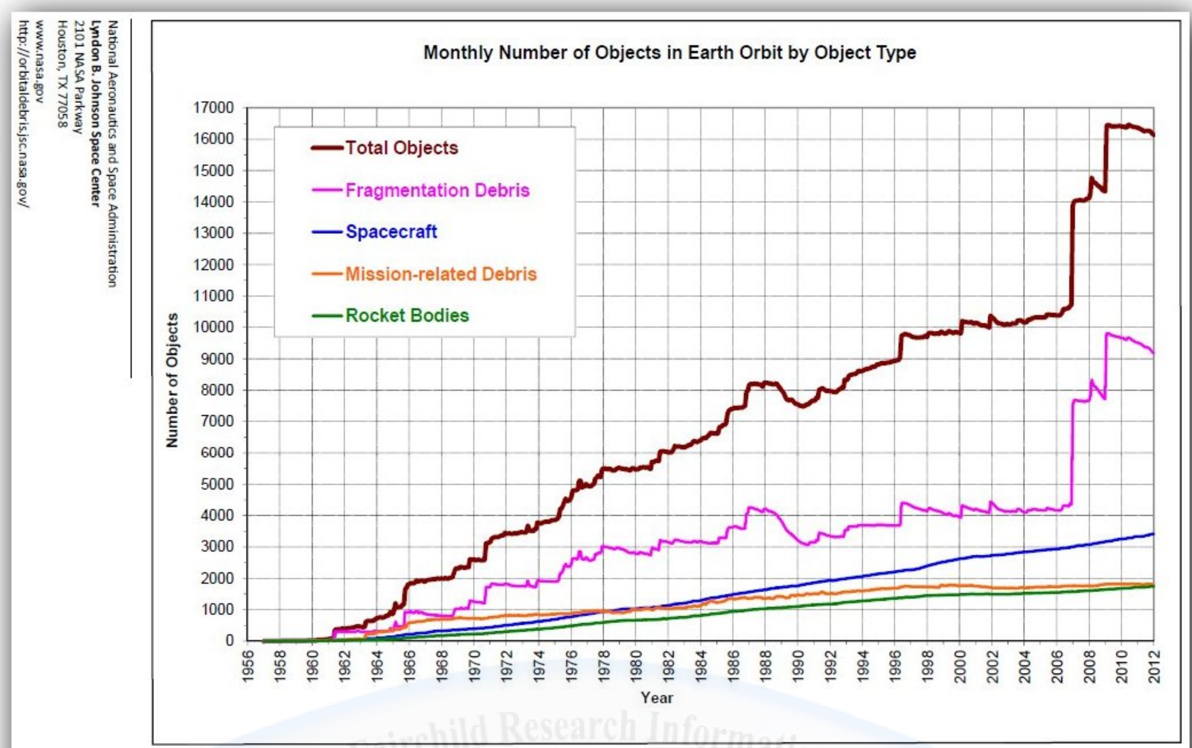


Figure 2: Crater in space shuttle windshield created by space debris

essence, a small projectile that is traveling at very high velocities and is simply waiting for an unfortunate target to find itself in the inevitable path of that projectile. Unlike projectiles that are inside the atmosphere, there are very few forces to create drag on projectiles above the atmosphere. Consequently, every piece of debris poses degrading or potentially lethal effects for every active satellite that may be unfortunate enough to be in the path of the debris because of the sheer velocity each object is traveling. Complicating this problem is the fact that when two objects collide in orbit, they create a substantial amount of additional debris. Since there is very little atmosphere to create drag on the debris, the debris pieces continue to orbit the earth at hypervelocity until they eventually decay from orbit or collide with other objects in their path. Obviously more debris creates more adverse effects. It is the proverbial snowball effect.

There are two recent events have vastly increased the amount of debris in orbit. First, the Chinese performed an anti-satellite demonstration on one of their inactive weather satellites, Fengyun-1C, in 2007. The international community chastised China for deliberately creating debris in low earth orbit, but China incurred no measurable retribution for the event. As of May 2010, 2,756 objects 10 centimeters or larger were still being tracked as a result of the Chinese anti-satellite test.[17] Second, an accidental collision between an active US owned Iridium 33 satellite and an inactive Russian Cosmos 2251 satellite occurred in February, 2009. This event left over 1,700 pieces of trackable debris and much of that debris is still in orbit today.[18] Figure 3, provided by NASA, shows how the cataloged space debris has grown in the last several years. As described above, there are significant increases easily attributed to the Chinese anti-satellite test in 2007 and Iridium/Cosmos collision in 2009.



Monthly Number of Cataloged Objects in Earth Orbit by Object Type: This chart displays a summary of all objects in Earth orbit officially cataloged by the U.S. Space Surveillance Network. "Fragmentation debris" includes satellite breakup debris and anomalous event debris, while "mission-related debris" includes all objects dispensed, separated, or released as part of the planned mission.

Figure 3: Cataloged objects in orbit with known launch origins

The graphic shows that there are approximately 16,000 total objects cataloged by the US Space Surveillance Network. In order to catalog debris, the debris must be associated with a specific launch. The Joint Space Operations Center (JSpOC) at Vandenberg Air Force Base is now tracking an additional, approximately 6,000 objects in orbit that cannot be associated with a specific launch and consequently Figure 3 does not depict the whole story. [19] As a matter of fact, the JSpOC is now tracking over 22,000 objects larger than 10 centimeters. Of those 22,000 orbiting objects, only about 1,100 are active satellites.[20] Currently, the majority of tracking done by the Space Surveillance Network is ground radar-based, which is why the 10 centimeter size is significant. Objects smaller than 10 centimeters are hard to distinguish from the ground,

especially if the objects reside further away from the Earth's surface. There are estimates of over 300,000 objects in the 1 to 10 centimeter range.[21] Needless to say, whatever the actual number is, the amount of debris is growing at a rapid pace.

Deconflicting the paths of orbital objects is another mission performed by the JSpOC. Depending on the value of the object in orbit, an imaginary pizza-shaped box of varying dimensions is placed around the orbiting object to screen for any other objects that might pass through that box. If the assessed probability is high enough, satellite operators will decide if a collision avoidance maneuver is required. For high-value objects like the International Space Station, NASA has defined the warning box as 1 mile by 30 miles by 30 miles (radial, in-track, cross-track), which corresponds to a probability of collision of 1 in 100,000.[22] Figure 4 provides a visual illustration of what the conjunction assessment screening box looks like.

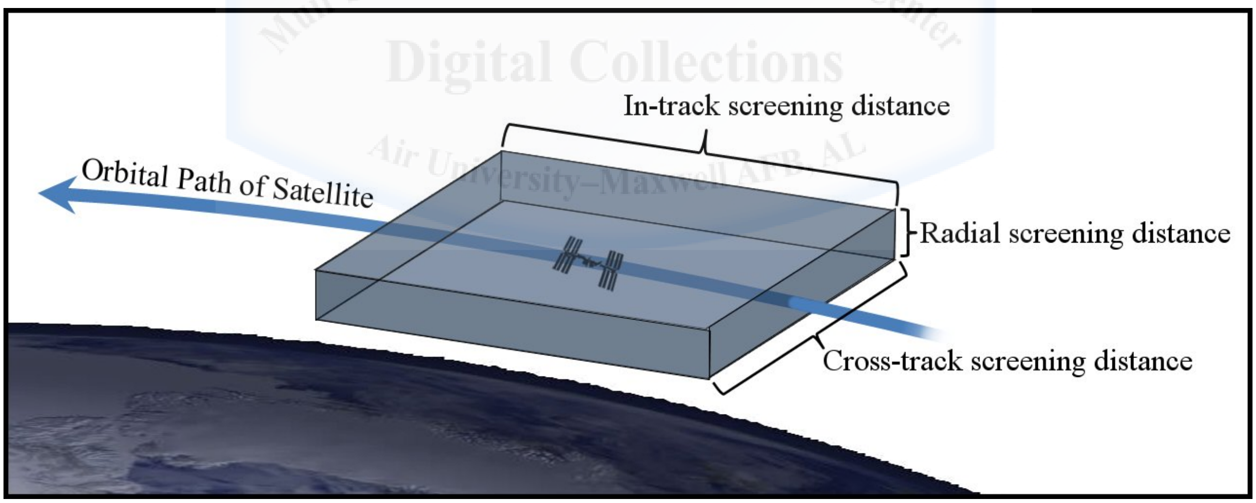


Figure 4: Imaginary box used for conjunction assessment screening

Unmanned payloads have a smaller screening box placed around them, but the frequency of conjunction assessments is rather large. In 2007, after the Chinese anti-satellite test, a member of the JSpOC team acknowledged that in an average week, there will be up to 200 incidents where a piece of the Feng Yun [1C] passes within 3 miles (5 kilometers) of one of

America's 400 satellites.[23] This reference is only discussing the debris created from the Chinese anti-satellite test and does not even take into account the thousands of other pieces of debris that satellites must be screened against. Computer software aides in the conjunction and collision avoidance assessments, but it requires a trained analyst to determine if the threat warrants a collision avoidance maneuver. Therefore, as space becomes more congested, the problems of collision avoidance will become more manpower intensive.[24] In fact, the International Space Station has been maneuvered several times to avoid debris from both the Chinese anti-satellite test and the Iridium/Cosmos collision.[25,26] Additionally, unplanned debris avoidance maneuvers of this nature shorten the effective life of the spacecraft by using valuable fuel reserved for keeping the satellite in its proper orbit. Further complicating this issue is the fact that moving a satellite to avoid one piece of debris might inadvertently put it in the path of another.

Some critics might argue that the debris problem is most prevalent in the lower regimes of Earth orbit, and that many of the critical capabilities described above are hosted on satellites that orbit further away from Earth than the majority of orbital debris.

This is partially true. Most of the major debris created recently exists in lower Earth orbit. However, many satellites and debris are in elliptical orbits that transverse both the near and far aspects of earth orbit. Therefore, a collision of a satellite in an elliptical orbit could have far reaching effects to all orbital regimes. Figure 5 illustrates how different orbits look with respect to

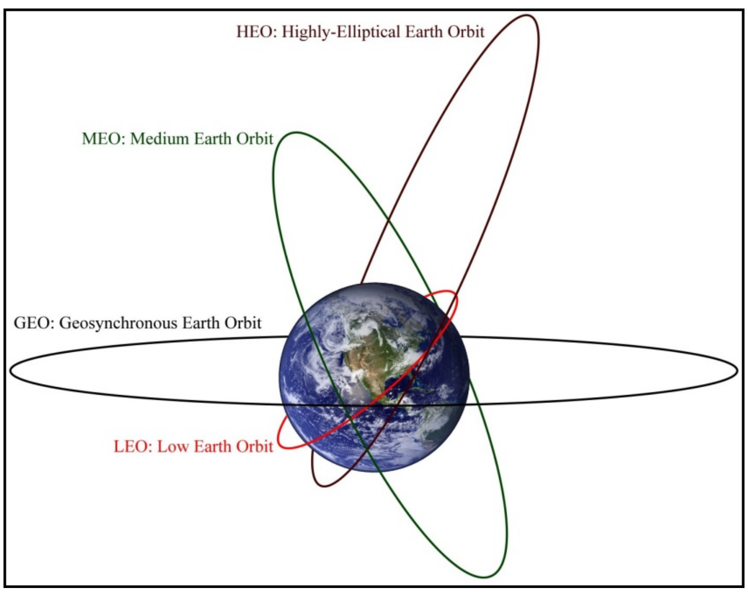


Figure 5: Basic orbits utilized by satellites

the Earth and each other. It also illustrates how uncontrolled debris in low earth orbit could impact objects in the highly-elliptical earth orbit and subsequently impact objects in medium earth orbit. Additionally, satellites placed in Geosynchronous Earth Orbit (GEO) are at risk of collisions as well because years of launches have created a very congested "belt" of active and inactive satellites around the globe. Recent guidelines published by NASA encourage that satellite owners reserve enough fuel to dispose of their geosynchronous satellites into a graveyard orbit approximately 300 km above the GEO belt.[27] However, these guidelines along with other debris mitigation techniques were not adopted until 1997 and only encourage voluntary compliance. Other countries adopted similar guidelines in 2002, and the United Nations endorsed a set of debris mitigation guidelines in 2008.[28] However, there does not appear to be any measurable retribution if an entity creates space debris in orbit. Additionally, a satellite that malfunctions at some point prior to its designated end-of-mission may not be able to be commanded into the disposal orbit.

There have been numerous other explained and unexplained breakups over the years polluting the space environment with more debris. It is not outside the realm of possibility that at least some of these unexplained breakups occurred as result of an impact from man-made space debris.[29] Recently, for example, a Russian satellite designed for an interplanetary mission to Mars incurred a failure and was stuck in low earth orbit. While the spacecraft's mission was already deemed a failure and officials awaited the inevitable orbital decay, the spacecraft inexplicably stopped communicating with its ground operators. The chief of the Russian space agency responsible for the failed spacecraft subsequently made comments that suggest the spacecraft was sabotaged by foreign forces. The Russian official stopped short of accusing any one nation, but implied that United States might be to blame for the spacecraft's malfunction.[30]

Yet with the amount of debris in low earth orbit, it is very plausible that the doomed Russian spacecraft was impacted by a small, yet lethal, piece of debris that rendered it inoperable. Regardless of the cause of the failure, international relations were not strengthened in the aftermath of the confrontational Russian accusations.

Conspiracy theorists might argue that the debris problem gives space faring entities an alibi regarding accusations of offensive counterspace tactics, that is, intentional actions to harm an adversary's capabilities without provocation. Without undeniable proof that an entity deliberately caused a satellite's demise, there will be a large degree of uncertainty as to the cause of death because the orbital debris could have caused the problem. This is especially true if it is a one-time isolated event. If an adversary knows your spacecraft is failing, an opportunity exists to test new offensive counterspace tactics and possibly get away with it because the enormous debris field will provide plausible deniability, especially since very few entities have the ability to track the objects on orbit. Nevertheless, this recent event with the Russian satellite highlights how inflammatory even the perception of a contested space environment can be.

Contesting the Space Environment

Many nations are currently developing capabilities to offset the asymmetric advantages that the United States maintains in the space domain. Not only are nations seeking indigenous space capabilities to further their own national objectives, but they are also seeking ways to negate the capabilities of the United States. This paper has already highlighted China's ability to contest the use of space capabilities by destroying a satellite through kinetic means. The United States and Russia have also demonstrated such abilities in the past and India has stated intentions of developing anti-satellite capabilities.[31] However, kinetic effects are only one way of contesting the space environment.

Interfering with the communications uplinks and downlinks through electronic frequency spectrum jamming is a cost effective way to negate a nations utility of space assets. In 2010, there were documented cases of intentional jamming of European communications satellites from within Iran. Unfortunately, due to the widely available and affordable technology required to accomplish frequency jamming, it is unclear whether the Iran-originated jamming was state-sponsored or generated elsewhere.[32] The benefits that the Global Position System (GPS) provide are widely known throughout the globe and the ability to jam GPS is becoming more and more prevalent. During the initial phases of Operation Iraqi Freedom, Russian made GPS jammers were employed to negate the use of GPS aided munitions and confuse the coalition partners who were relying heavily on GPS for navigation.[33] Additionally, North Korea demonstrated its ability to jam GPS signals over the course of three days in August of 2010.[34] In fact, low-power GPS jammers can be purchased directly from the internet for purposes of "vehicle tracking denial" and some have a denial range of 40 meters.[35] It stands to reason that if companies are in the business of selling low-power jammers, they could easily be in the business of selling high-power jammers. Figure 6 illustrates how easily accessible this technology is to anyone with a computer.

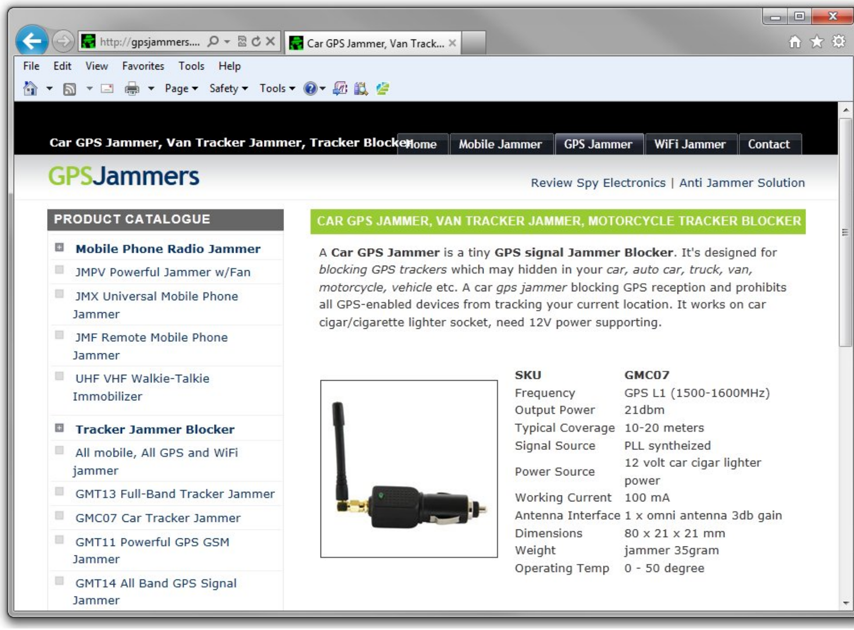


Figure 6: Low-power GPS jammer for sale by www.gpsjammers.net

Another way to negate space capabilities is through directed energy. Ground-based laser technology is continuing to be developed for a variety of purposes. While lasers can be used for a variety of beneficial purposes including satellite communications, they can also be used in a military manner for defensive and offensive operations. Lower power lasers could be used for temporary effects, such as blinding or dazzling a satellite's sensors, whereas higher-powered lasers could produce damaging and irreversible effects.[36] A number of countries, including Russia and China, have shown interest in developing high-powered laser capabilities.[37] Just like the affordability of the GPS jamming technology, increasingly advanced laser technology is making its way into the commercial market. For example, anyone can purchase a hand-held green laser pointer from the internet for $999 that has a beam distance of 85 miles.[38] The same website, owned by a Hong Kong based company, sells a blue laser touted as the "world's most powerful handheld laser."[39] Figure 7 illustrates how affordable laser technology is becoming.

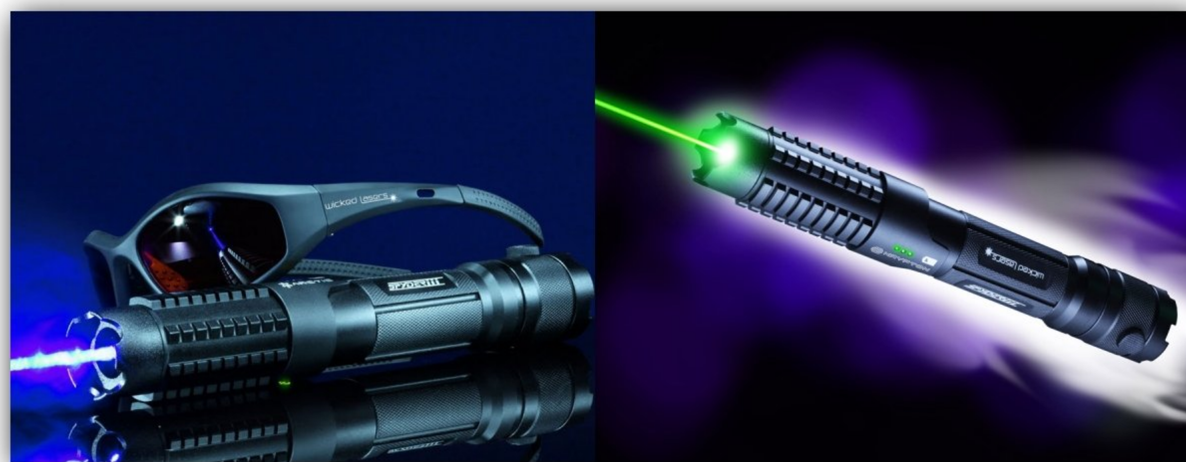


Figure 7: Blue and green handheld lasers available for purchase from www.wickedlasers.com

Orbital location and frequency allocation are also sources of contention among space faring nations. While the U.S. makes the GPS signal available for world-wide users, presumably there must be at least a little distrust that the U.S. will not always provide this capability, especially in times of conflict. To that end, China, Russia, the European Space Agency, India, and Japan are all developing a stand-alone constellation of satellites for position, navigation, and timing.[40] Consequently, the duplication of effort crowds the orbital regimes and frequency spectrum where these satellites reside. These demands on orbital slots and frequency spectrum extend to all the orbital regimes depicted in Figure 5.

Significance to National Security

The United States military is especially dependent on space capabilities. General William Shelton, Commander of Air Force Space Command, summed it up when he provided the opening remarks at the 27th National Space Symposium. "Our dependence [on space] has never been higher. In fact, it's integrated into how we fight wars today so deeply that it is hard to imagine taking space out of the equation."[41] The United States utilizes space capabilities in all aspects of warfare including: strategic and tactical communications, position, navigation, and

timing, weather forecasting, intelligence, surveillance, and reconnaissance operations; missile warning and defense, personnel recovery, and precision weapons employment. Not only are these missions vitally dependent on space capabilities to enhance their effectiveness, but the capability to perform some of these missions, remotely piloted aircraft for example, might cease to exist altogether without space-based systems.

The Chinese have also taken notice of the importance of space. While it is unknown if the Chinese have an official doctrine for space operations, they recognize that without the control of space, it will be virtually impossible to maintain dominance in the air and sea domains.[42] Chinese authors have noted that whoever gains space dominance will be able to influence and control other battlefields and will likely retain the initiative and reduce an opponent to the reactive and passive stance.[43] Additionally, the Chinese have observed the extensive reliance of US forces on space-based assets in recent operations and it appears that their perspective is that the U.S. sets an example worth following.[44]

The implications of losing space capabilities would have far-reaching effects within social, technological, economic, environmental, and political circles. GPS alone touches every one of those circles, and examples can be provided showing how it is utilized ranging from financial markets to farming. Additionally, space capabilities provide equally vital support to global stability, and these capabilities are identified in the current *National Space Policy* where it states:

> The utilization of space has created new markets; helped save lives by warning us of natural disasters, expediting search and rescue operations, and making recovery efforts faster and more effective; made agriculture and natural resource management more efficient and sustainable; expanded our frontiers; and provided global access to advanced medicine, weather forecasting, geospatial information, financial operations, broadband and other communications, and scores of other activities worldwide.[45]

In short, space capabilities provide stability in a dynamic world. Instability lends itself to conflict, and conflict whittles away at national security.

Driving Forces

While the international community is interconnected more today than anytime in human history, there are a number of forces that are continuing to shape the landscape of international relations and by extension, the space domain. There are arguably many more subtle forces contributing to this shaping, but this paper aims to identify the overt forces that could have the greatest impact. These forces include: the International Traffic in Arms Regulations, global energy demands, and emerging cyberspace capabilities. Each of these forces by themselves may not be detrimental to national security, but when blended together, they may inadvertently create the perfect storm that is capable of shattering the US national security in a heartbeat.

International Traffic in Arms Regulations (ITAR)

In 1999, legislators decided that it was in the United States' best interests to restrict the export of satellite technology in the same fashion that weapons exports were restricted. This was deemed essential to preserve the US technological edge in space. However, the maneuver to preserve domestic space capabilities actually had the opposite effect.[46] ITAR restrictions on satellite technology have crippled the US space industrial base by limiting the amount of the global market that manufacturers can access. Essentially, the only customer available to buy satellites or components from companies within the United States is the US government. At the same time, this caused the other space faring nations of the world to develop their own indigenous space technologies and then market them throughout the rest of the world as "ITAR-free."[47] So not only did the United States not maintain the technological edge in space, the rest of the world caught up while the US space industrial base withered. The damaging effects of

including satellite technology as an export controlled item have been highlighted in many documents in recent years.

In an attempt to reverse the damage, the House of Representatives introduced a bill, H.R. 3288, on November 1, 2011. If passed, this bill would remove commercial satellites and related components from the United States munitions list subject to certain restrictions.[48] This is only the first step in getting satellites and components removed from ITAR restrictions. The bill is still in review and needs to be voted on by the House and Senate before the President can sign it into law. Even if the bill does pass, only time will tell whether or not the policy reversal was implemented soon enough to allow the US space industrial base to recover.

Energy Demands

Large industrialized nations are huge consumers of energy. As globalization evolves the economic landscape of the planet, more nations are becoming modernized and the demand for

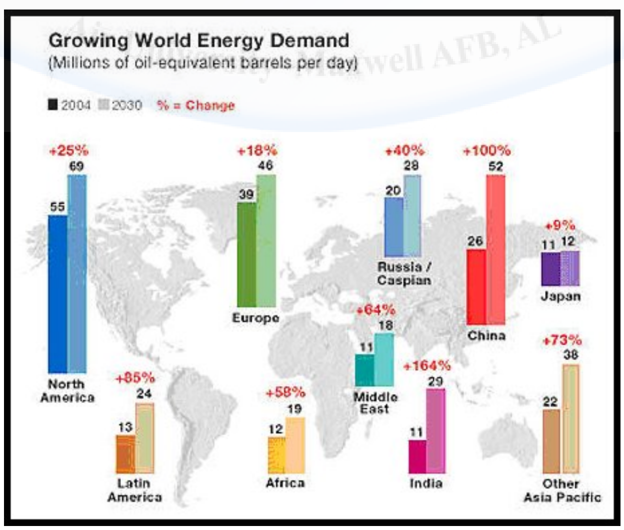


Figure 8: Forecast of world energy needs

energy continues to rise. One estimate forecasts the world demand for oil in 2025 will be 60% greater than it was in 2007.[49] Figure 8 illustrates this forecast out to 2030. The problem is that while the demand for energy is going up, the discovery of new energy sources is not keeping pace with the demand. Another report by an activist group in New York City paints a dire picture of the future of oil production and discovery and is depicted in Figure 9.[50]

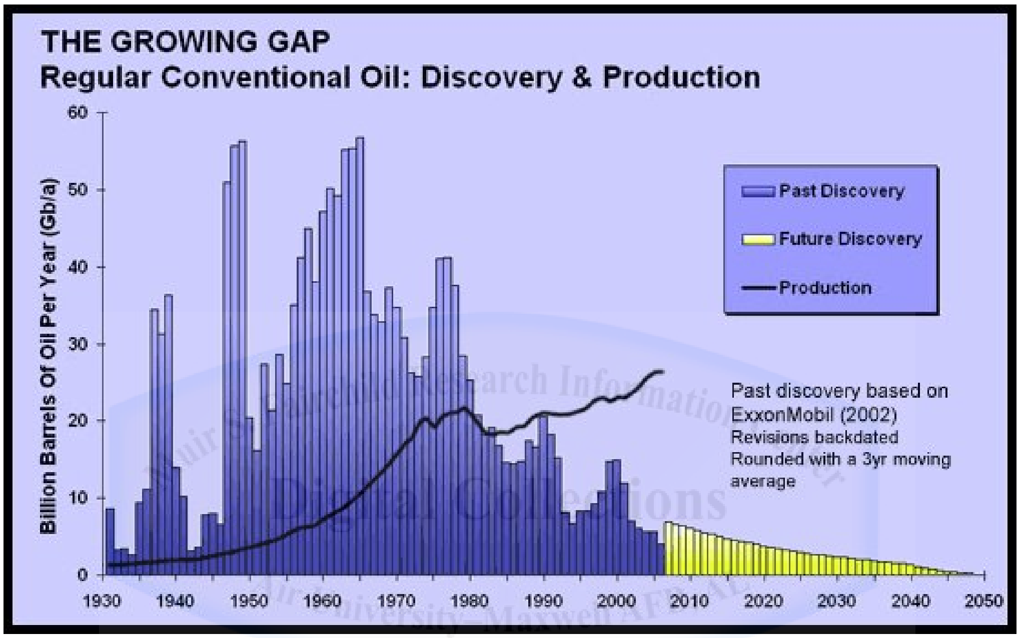


Figure 9: Oil discovery and production estimates

The world is in a continuous search for additional oil reserves. In fact, satellites have aided in the efficient discovery of new oil deposits.[51] Melting of the polar ice caps has caused nations to lay claim to areas in those vicinities in order to exploit any resources that may be available. Antarctica, for example, is estimated to have the world's third largest oil reserve at 203 billion barrels, and both China and Russia have expressed interest in the resource potential of the Antarctic continent region.[52] This is contrary to a treaty system that is place prohibiting any activity relating to mineral resources other than for scientific research.[53] As countries push the boundaries of the treaties agreeing to the peaceful use of the global commons, such as Antarctica and space, sooner or later a nation is going to step up and declare enough is enough.

One of two scenarios may occur. Either one nation will get confrontational with another about activities which do not align with treaty guidelines, or the treaty will be pushed aside in a free-for-all of anarchy-like behavior among those nations with interests in the region. Either scenario is not good for stability of the global economy.

Alternatives to oil are being researched daily such as wind, solar, synthetic and bio-based fuels, but none of these are capable of producing the amount of energy that is contained in a drop of oil or is not capable of being produced at the current consumption rates of oil. Recent years have seen the price of oil skyrocket. This can and will have a direct impact on national security. If the price of oil rises, then transportation costs will rise. The cost of anything transported by air, land, or sea will rise. The rising costs of transporting goods will be passed on to the consumers. This will create a downturn in the economy because consumers will have less buying power. A weak economy will have a negative impact on military strength. And a weakened military will put national security at risk. Unless an alternative energy source is found in quantities that sustain the demands of the world, nations will pursue politics by other means (i.e. conflict) to ensure their energy demands are met. If conflict erupts as a result of scarce energy sources, then a nation's space-based assets will be some of the first casualties of the conflict.

Emerging Cyberspace Capabilities

Exploitation of cyberspace vulnerabilities extends into the space domain. Recently, Bruce Carlson, Director of the National Reconnaissance Office declared: "I believe that one of the great engines of this world is the combination of space and cyberspace." [54] Satellites and ground stations all depend on computer hardware and software to execute their missions. However, it is this dependence that puts these systems most at risk to an attack. Each satellite's

mission, at the core, is simply the act of moving pieces of information from point A, to point B. That information may contain a timing signal, pixels of a picture, or an execution order for synchronized operations on a battlefield. Disrupting the information flow from one entity to another is at the heart of offensive cyberspace capabilities. From the quote above, Director Carlson, believes that space and cyber space are inextricably linked. The Chinese have also concluded this and have noted that the combination of modern information technology and military space systems is the backbone for coordinating land, sea, and air forces. Additionally, they have published articles in media outlets that state "information dominance cannot be separated from space dominance." They follow with "seizing space dominance is the root for winning the informationalized war."[55] One might equally argue that since cyber and space are so intertwined, seizing the cyber domain might be an inlet to achieving space dominance.

Like airpower in the early 20th century, the cyber realm emerged through advancements in technology, and it was not readily evident to military theorists exactly how the capabilities and vulnerabilities of this technology could be fully exploited in a military environment. Enter the hackers. Individuals with technical savvy and a little extra time on their hands were able to find the security holes within cyberspace and exploit them for the fun of it. As these attacks became more sophisticated in nature and as more critical functions of society were placed on the "grid", it became apparent that these hackers could inflict real damage to critical infrastructure if they wanted to.

There are two examples which illustrate how easily damage can be inflicted through cyberspace channels. First, hackers interfered with two US government satellites four times in 2007 and 2008 through a ground station in Norway. While no overt damage was cited, it was acknowledged that someone else had complete control over those two satellites for a few minutes

of each occurrence. The 2007 occurrences were not even realized until after the 2008 breach was tracked. While the perpetrators are not able to be identified with certainty, evidence suggests the breaches originated in China.[56] Second, a breach of NASA's Jet Propulsion Laboratory allowed hackers to gain full functional control over networks that contained sensitive files on "mission-critical" systems.[57] Like the previous example, origins of the attack were identified inside China. NASA has been the target of attacks like this in the past. The space agency reported 5,408 incidents of malware and unauthorized access in 2010 and 2011 alone.[58] Attribution of the cyber attacks proves to be just as problematic as the attacks themselves.

As implied above, it is very difficult to discover a cyber breach, and equally difficult to figure out whom is to blame. Complicating this problem is the fact that almost anyone with internet access has the tools necessary to initiate an attack. Unlike access to space, which is very expensive and requires huge investments usually backed by a nation's government, access to cyberspace can be accomplished with a small computer and a trip to the local coffee house. Attribution is difficult, but not impossible. NASA has conducted 16 investigations in the last five years that resulted in the arrests of foreign nationals from China, Great Britain, Italy, Nigeria, Portugal, Romania, Turkey, and Estonia.[59] However, the threat in cyberspace is continuing to grow rapidly. In fact, the director of the FBI, Robert Mueller, recently stated that "in the not-too-distant-future, we anticipate that the cyber threat will pose the greatest threat to our country."[60] The linkages between cyberspace and space, and the growing offensive capabilities in cyberspace pose legitimate challenges for any nation seeking to maintain dominance in space.

Future Scenarios

The contesting and congesting of the space domain identified in the preceding paragraphs allows one to speculate what the future may hold if these trends continue. While the United States definitely has much to lose, sustaining a healthy global commons, such as access to space, benefits the whole planet. The following section presents some fictional, yet plausible, scenarios that policy makers should consider for the future well-being of the space domain. Scenario 1 will envision an optimistic world where cooperation has triumphed over conflict. As a result of this cooperation and a shared desire to prevent catastrophe, solutions are found to some really hard problems. Scenario 2 encompasses the prospect of the U.S. engagement in a conventional conflict with another nation state. The adversary nation is well aware of the US dependence on space assets and exploits that dependence fully. Scenario 3 provides an outlook of US involvement that gets thwarted by a non-state actor through the means of cyberspace. Like Scenario 2, the US space superiority is taken away rather quickly which has a cascading effect on all other operations.

Scenario 1: Greater Cooperation Spurred by Catastrophic Accidental Event

In the year 2015, the Chinese space program was accelerated at a rapid pace and by 2020, China was only the second country to put men on the moon. Their space program was robust and they realized the advantages that space technology contributed to other aspects of society. As the major space powers had realized before them, the Chinese concluded that having an orbital laboratory like the International Space Station (ISS) would further the progress of space-based technology for all mankind. However, the Chinese were also well aware of the $100,000,000 price tag and the plethora of nations that supplied funding to make it a reality as well as the years it took to construct the football-field sized orbiting laboratory. Therefore, in an

unprecedented move of international diplomacy, the Chinese sought inclusion as the 16^{th} nation to partner on the ISS. Meanwhile, since the Space Shuttle retirement in 2011, NASA was struggling to build their next-generation launch vehicle and like many government space acquisition programs, they were over budget and behind schedule on their replacement rocket. Originally planned for a 2017 launch, the Orion vehicle still had not seen its first developmental flight by 2020. Therefore, the Chinese partnership provided additional resources for NASA to take advantage of in the interest of space exploration. The partnership was not seamless by any stretch of the imagination, but by the year 2023, the Chinese were able to construct, dock, and occupy the first Chinese-made segment of the ISS.

However, the triumph of this merger was short lived. In the year 2024 the Joint Space Operations Center (JSpOC) at Vandenberg was now tracking over 40,000 objects the size of a baseball or larger. Most of these 40,000 objects were debris residing in low earth orbit. The ISS had been making collision avoidance maneuvers on the order of one per week so it was becoming a fairly routine procedure for the crew of the space station to seek shelter for a near-miss or to fire the thrusters and maneuver the ISS out of harm's way. The conjunction assessment of June 28, 2024, was different. As orbital analysts made calculations and ran computer models to determine how much to maneuver the ISS to avoid a French rocket body launched in 1996, a piece of debris the size of a golf ball punctured the skin of the ISS and caused a small, localized explosion that ripped a bigger hole in the crew's living quarters. All eight crew members on board, including two Americans, two Russians, two Chinese, one Italian, and one Japanese, were instantly killed when the compartments rapidly decompressed. Unfortunately, this horrific event was witnessed by the world as the ISS crew was assembled for

a live question and answer session with a third-grade class in Fairfax, Virginia when the event occurred.

In addition to destroying the functionality of the space station, the small explosion put the station into an uncontrolled spin and ground controllers were unable to use the onboard thrusters to stabilize the ISS or maneuver it away from additional debris it might encounter. Each week that passed increased the amount of debris on orbit as the ISS encountered collisions with other uncontrolled objects. Within a couple of months, several functional satellites from various countries had been destroyed as a result. It was only a matter of time before the entire orbital regime became an unusable cloud of lethality to anything in orbit for the foreseeable future.

This tragedy spurred a cooperative effort that spanned the globe. Instead of abandoning the space program as many advocates suggested, the major space-faring nations from around the world rallied to solve the issue of debris in space. Several concepts for clearing orbital debris had been considered in the past but were always considered unacceptable because any concept that could clear away debris could also be used as an offensive capability. However, now that the viability of space as an enabling domain was at risk, all ideas were being considered. In the quest to find an alternative to oil as an energy source, some new renewable and sustainable propulsion systems were accidentally discovered that allowed satellites to maneuver in space without the need for storing a limited supply of onboard propellant. Additionally, in early 2025, a new Treaty for the Peaceful Uses of Outer Space was drafted and immediately signed by over 100 countries. The verbiage in the treaty specifically addressed vehicles on orbit that could be utilized for clearing, but explicitly restricted them from being used for offensive operations. Consequently, the United States Congress finally succeeded in removing satellite technology from the ITAR restriction list, allowing for greater cooperation and technology sharing between

nations. Finally, an advanced multinational space situational awareness system was built and fielded to assist in the detection and prevention of on-orbit collisions. As a result of this increased trust and cooperation between nations, a viable system was designed, developed, and fielded to collect and remove the debris from Earth orbit. A great deal of capability was lost in the years following the ISS accident, but the cooperation that ensued afterward provided the world with a renewed faith that cooperation in the face of catastrophe, coupled with the national will of many nations working together towards a common end, could achieve what was once thought of as unattainable.

Scenario 2: Adversary Nations Pose Legitimate Threat to Allied Space Assets

In the year 2015, the Chinese space program was accelerated at a rapid pace and by 2020, China was only the second country to put men on the moon. The quest to find an alternative energy source to oil had failed miserably at this point and the world oil supplies were continuing to grow scarcer as the demand continued to grow. In a bold move, China began drilling for oil off the coast of Antarctica, despite pressure received from several other countries who attempted to lay claim to that region. Several countries attempted to apply diplomatic and economic pressure on China in the hopes of deterring them from exploiting the Antarctic region for its resources, but none of the attempts were even remotely successful. At the height of tensions in 2022, China suffered an accident on one of their offshore drilling platforms similar to the British Petroleum accident of 2010 in the Gulf of Mexico. Millions of gallons of crude oil were released into the water and polluted the pristine white landscape of the Antarctic coastline with a brownish black sludge for over a hundred miles. This incident was not well received in the international community. In particular, Australia wanted China to completely clean up every inch of Antarctic coastline and remove every oil platform from the region. Furthermore,

Australia was ready to use military force even though they knew they were outmatched militarily by China. China refused to stop drilling for oil and by the autumn of 2024 had not cleaned up the spill to Australia's satisfaction. Therefore, Australia requested assistance by forming a coalition with the United States and about 20 other nations including the majority of the European Union. The coalition tried to apply diplomatic and economic pressure to China, but that only invoked the onset of hostilities.

Once the shooting began, the Chinese began to target assets in space because they were well aware of the coalition's dependence on space assets. High on the space target list were the Global Positioning System (GPS) satellites. China managed to destroy four satellites within 24 hours. Initially, this only provided some positional degradation to anything that utilized a GPS signal. But after a couple weeks, the debris created from those first few attacks began to impact other GPS satellites; knocking them out one by one. Furthermore, the European navigation system, Galileo, and the Russian navigation system, GLONASS, also became victims to the hazardous debris because they reside in the same orbital regime. This provoked Russia to join the coalition. Before long, all navigation satellites from all nations placed in Medium Earth Orbit were rendered useless. Meanwhile, the Chinese navigation system, Beidou, which achieved a global navigation capability in the year 2020, was unaffected because it resides at a higher geosynchronous orbit. The loss of GPS and other Medium Earth Orbit navigation satellites not only impacted the military machines that use GPS for navigation and targeting, but it also impacted financial institutions the world over that synchronize money transfers using the GPS timing signal. By the spring of 2025--almost literally overnight--the United States and many other nations' economies were turned sideways because the plastic everyone carried in their wallets no longer had any buying power.

The cascading effects of the loss of GPS ripped through the coalition from top to bottom and for the first time since the inception of the US Air Force, the United States was not the technologically dominant force on the battlefield. The Chinese began to strike targets at will while coalition forces scrambled to develop tactics that did not involve space assets. Before long, the coalition no longer had the capacity to fight. China became the world's dominant superpower and their demands were simple. They wanted complete ownership of the Antarctic continent to fully exploit as they saw fit. The rest of the world looked on as they tried to pick up the pieces of their own shattered nations. Obviously this qualified as an act of contesting the space environment while at the same time creating thousands of additional pieces of debris in orbit that had lethal effects on other satellites. The era of space superiority that the United States spent decades building and defending was taken away in the blink of an eye.

Scenario 3: Non-State Actors Pose Legitimate Threat to Allied Space Assets

In the year 2015, the Chinese space program was accelerated at a rapid pace and by 2020, China was only the second country to put men on the moon. This accomplishment spurred a second space race between the United States and China, but on friendlier terms than the Cold War space race with the Soviet Union. Technology advancements continued to develop during this time period, and computer processing power had actually attained what was perceived as the theoretical limitations of what was physically possible. Revolutionary advancements were made in the fields of voice recognition and artificial intelligence, with China leading the way in these fields of research. The year 2022 marked a milestone in the digital era because it was the year that literature of all forms became available in electronic format and accessible from the internet. Even classified military documents became accessible through unclassified channels, and no amount of security measures seemed to prevent these breaches. Consequently, anyone with a

computer and access to the internet could literally speak into their voice recognition software: "build a virus to turn off all functioning satellites owned by country X." The software would then perform research through the internet automatically and find all necessary schematics and build a specific blueprint of the system with vulnerabilities that could be exploited and then design a virus to defeat it. While computer forensics also made huge advances up to this point, attribution of criminal activity through cyberspace was still problematic. It took weeks to pinpoint perpetrators of cybercrime, and the voice recognition software easily allowed individuals to cover their tracks simply by asking the computer to do it for them. Building and implementing such a virus was literally as easy as saying the words. This is exactly what happened on November 17, 2024.

After removing combat troops from Afghanistan in 2014, the United States had refrained from leading international involvement in any regional conflicts for ten years. However, the instability once confined to Somalia had now spread to Ethiopia, Kenya, and Mozambique. A dictatorship had emerged in that region that was gaining great economic and military power through pirate operations in the Indian Ocean and enormous illegal drug operations. Fearing the continuation of this trend and the lack of international involvement to stop it, South Africa made a conscious decision to re-invigorate their nuclear weapons program in 2023. The United States, still maintaining their policy of counter-proliferation of nuclear weapons, agreed to lead a coalition to stabilize the situation if South Africa did not reinstate their nuclear weapons program. After prepositioning forces in South Africa, Madagascar, Saudi Arabia, and Chad, the coalition effectively began stability operations from all possible angles on August 8, 2024. Instead of massing huge forces in these locations, the coalition relied heavily on space and cyberspace to enable precision effects on the adversary. Operations were progressing as

expected because the US forces had spent the previous ten years developing their doctrine to include operations of this nature. However, on November 17, all communications between coalition forces ceased. A computer virus code named “Sire Launch” successfully infiltrated US satellite ground stations and effectively caused all US owned and operated satellites to turn off. Once the virus successfully turned off all operating satellites, it then systematically erased all lines of code from each ground station computer. This effectively crippled the coalition forces and disrupted the daily lives of approximately four billion people across the globe that benefited from satellite services daily. It was weeks before the United States was able to reinstate the satellite constellations and by that time the damage was done. While the coalition was blind, deaf, and disoriented, the Somali dictatorship used its guerilla tactics to push through coalition forces and take the country of South Africa. The coalition mission failed. Cyber forensics were never able to piece together where the cyber attack came from. They were only able to discern that it was not a state-sponsored act, and that the letters of “Sire Launch” when rearranged spelled “China Rules”. Furthermore, the highly sophisticated virus had been residing in the US systems for over two years before it became active.

Even though the space domain was exploited long before the cyber domain emerged, space became an extension of the cyber domain for all practical purposes. The co-dependence of space and cyber allowed for more avenues of exploitation with respect to assets in orbit. This coupled with the accessibility and anonymity of the internet allowed for mischievous actors from all walks of life to contest any nation’s space assets simply because they could.

Conclusions

Regardless of the scenario, the triad of space congestion, contesting of the space domain, and the few identified driving forces provide several plausible, yet dire outcomes for the future

of US space superiority. Whether the threat comes from a nation state, a rogue non-state actor, or an inanimate piece of space debris launched several decades ago, a solution needs to be pursued with the highest of priorities. While the scenarios above can all be considered fictional, they are all based in truth and trends that are being faced today. The congesting of space and the contesting of space are undeniably trending in the wrong direction to ensure US space superiority remains intact. Several driving forces such as ITAR restrictions, energy scarcity and demands, and emerging cyberspace capabilities have the potential to offset the delicate balance that currently exists on the global scale. In order to maintain this balance, a few recommendations are proposed.

Policy Changes/Recommendations

Policy makers have already identified some of these issues and are advocating for solutions, but more needs to be done than just talking about the issues. Some entities are exploring concepts that would in theory be capable of cleaning up the space domain. However, most of these future concepts are discarded immediately because they are too expensive or the technology does not yet exist to pursue the concept. Most of these concepts would receive widespread resistance because anything that is capable of removing space debris would also be capable of performing offensive operations to an adversary's satellites. A few recommendations are presented here to spur finding a solution to the contesting and congesting of the space domain.

First, the US Congress needs to remove non-military satellite technology from the International Traffic in Arms Regulations. There are parts and components that have been developed specifically for military applications, sensors for example, but simple components that might be common to all satellites could certainly be removed from ITAR restrictions. This

would allow US-based companies that build satellite components to market them the world over, thus enabling growth in the US space industrial base. Growth in the US space industrial base would allow more emphasis in space technologies that are more capable. At the same time, it would most likely slow down the growth of space capabilities in other countries because they could buy their components from US-based companies instead of designing their own. This, in turn, may lead to more dependency between nations and provide fewer opportunities for conflict. Ultimately, an increased space industrial base for the United States may discover that critical technology necessary to make space debris mitigation feasible and affordable.

Second, in the interest of building some type of device that is capable of cleaning the space environment, a new Treaty for the Peaceful Uses of Outer Space should be drafted to specify that any device developed for debris mitigation cannot, in any way, be utilized in an offensive manner. Furthermore, legitimate punishment and enforcement mechanisms should be identified in the treaty for any nation that deliberately performs actions contrary to treaty guidelines. Additionally, the treaty should have provisions for offensive actions that originate from non-state actors. Encouragement should be given to nations that prosecute individuals or groups who inflict disruptive actions upon another nation's space assets. The nationality of each non-state perpetrator should determine which nations are ultimately responsible in such events. Even today, it is easy for someone to implement disruptive effects from nearly any location on the globe. Therefore, if an attack was carried out by on a nation's satellite by a non-state actor, and it was later determined that the non-state actor was from China, then China would be held responsible to remedy the situation, both with the nation whose satellite was attacked and with the individual who initiated the attack. The remedy would be situation dependent. It may seem harsh to hold an entire country liable for the actions of one lone actor, especially if that actor is

rogue or has officially denounced his citizenship. However, that is exactly the incentive needed to spur cooperation from all parties to curb such heinous activities. Ideally, this would create a cooperative environment where every country had a vested interest in preventing non-state actors from contesting space assets.

Third, to support this type of treaty, vast investments should be made in the area of space situational awareness to apply attribution to any "accidents" that occur in orbit. While investments are currently being made in this area, it is not yet enough to provide a full understanding of what is going on. Due to positioning of ground stations and limited space-based observation capabilities, many satellite operators from various countries must go for periods of time without communicating with their payloads. Further complicating this issue is the lack of cooperation between some nations with respect to sharing information on the positions of their satellites. Obviously, a nation would be reluctant to share positional information on their classified military payloads, but it would be a step in the right direction to share information on the non-military payloads. Having greater space situational awareness would benefit all space-faring nations by allowing everyone to definitively understand what happened instead of to speculate in the event of an anomaly. Furthermore, whether or not actions performed on orbit were accidental or deliberate would no longer be in question.

Fourth, special attention should be given as to how satellites and ground stations can be infiltrated through cyber technology. Technology advancements are difficult to predict. Often, as soon as a new technology has been developed, someone discovers a new way to do harm with that technology. This is also true of the cyber domain. As the world continues to become increasingly interconnected through space and cyberspace, more assets become vulnerable to malicious behavior which can be easily initiated by individuals from the other side of the planet.

Fortunately or unfortunately, the world has grown accustomed to the benefits provided by space assets. A disruption to the overarching architecture that sustains space assets would have catastrophic effects worldwide. Therefore, it is imperative that satellite hardware and software as well as the ground sites and the communications links that are used between them are safeguarded to the highest extent possible. Otherwise, any vulnerability that exists will certainly be discovered and exploited.

Fifth, greater emphasis should be placed on finding an alternative source of energy that rivals oil. Some companies today are researching alternatives to oil, but they have not been able to reproduce the sources at a sustainable rate to meet the consumption, or the energy contained just does not measure up to oil. If the world were able to gradually wean itself from oil, many conflicts may be averted in the future. Perhaps the discovery of this alternative energy source may even lead to technologies that allow for an affordable concept to clean up the space domain, and two birds could be killed with one stone.

This paper provides some insight into growing trends of space congestion and the contesting of space assets. Through the scenario-based methodology, driving factors were identified that were, in turn, incorporated into plausible scenarios which painted a rather grim outlook if the trends continue. While decision makers are readily aware of the trends mentioned in this paper, few actions have taken place aside from new policies to rein in the congesting of space. It is this author's recommendation that more could be done to help alleviate what may become the downfall of US space superiority. Nobody said it would be cheap, but the capabilities that space provides daily would be sorely missed and most likely would plunge the world into a level of chaos that has not been known before.

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